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SCALE INSECTS: WHAT THE ARBORICULTURIST NEEDS TO KNOW ABOUT THEM

by William E. Wallner

Abstract. Scale insects are among the most damaging pests of shade trees and shrubs, yet they are poorly understood. This article summarizes information on the biology, feeding mechanism in relation to host damage, and control of the major scale groups.

Scale insects are often not detected until trees or shrubs show advanced signs of injury. Their biology is poorly understood by many arboriculturists, which complicates efforts to cope with them effectively. The purpose of this paper is to provide the arboriculturist with the information he needs to deal with scale-related tree problems.

There are seven families of scale insects that inflict serious damage on shade trees and shrubs (Baker 1972). Of these, armored scales (Diaspididae), soft scales (Coccidae), pit scales (Asterolecaniidae), margarodid scales (Margarodidae), and eriococcid scales (Eriococcidae) are among the most widespread and destructive. Many are host-specific, such as *Cryptococcus fagi* (Baer.), which feeds only on American or European beech. Others, like oyster-shell scale (*Lepidosaphes ulmi* (L.)), feed on over 100 hosts. Some, such as San Jose scale, may differentially infest various plant parts (Kozar 1976). Some scales, when feeding on various parts of the same tree or upon different hosts, develop into such dissimilar forms that they appear to be separate species (Stannard 1965).

Biology

Scale insects, like all insects, have an external skeleton (exoskeleton) that must be shed in order for them to grow. Shedding of the skin is called a

molt; the period between molts is called an instar. Typically, for scale insects, there are three molts for the female and four for the male during each generation (Figs. 1, 2). The first molt results in the loss of legs and antennae, but the scale remains attached by its mouthparts (stylets). During subsequent growth a waxy secretion is produced that further anchors the scale to its host.

Not all scale insects have males; some females are capable of producing living young in the absence of males. When present, males are fragile, weak flyers and live for only 1 or 2 days, during which time they mate (Fig. 3). The females of certain scales produce a volatile chemical (sex pheromone) which attracts males for mating (Roelofs et al. 1977). Pheromones are unique and specific to each species; they are currently being investigated for use in traps to monitor and detect scale populations.

Although each scale insect is unique in its behavior and life history, it is possible to make some general comparisons. The armored and soft scales, which contain the largest number of injurious tree pests, illustrate the more important habits and development traits.

Armored scales. The armored scales secrete a covering, called a test or cover, that protects their bodies. In males, the covering is a filamentous, waxy, fragile material; in females it is hard and impervious, and covers the eggs as well (Fig. 1). Examples of this group are the oyster-shell scale, *Lepidosaphes ulmi* (L.), San Jose scale, *Quadraspidiotus perniciosus* Comstock, juniper scale, *Carulaspis carulli* (Targ.), pine needle scale, *Phenacaspis pinifoliae* (Fitch), florinia hemlock

scale, *Fiorinia externa* Ferris, and others.

During cold weather they exist most commonly as eggs beneath the scale covering, or as immature males and females, or mated mature females. Eggs hatch beneath the female scale covering and the first instars migrate to the new growth and immediately settle and insert their mouthparts. The first instar is called a crawler, because it possesses legs and is the only motile stage, with the exception of adulted winged males (Fig. 4). The crawler stage may be dispersed by wind, rain, or carried on the bodies of birds, other insects, or mammals. Crawler dispersal usually is limited to short distances. Man's activities contribute significantly to long distance dissemination by moving infested plant material.

Soft scales. The soft scales (Fig. 2) include European fruit lecanium, *Lecanium corni* Bouche, cottony maple scale, *Pulvinaria innumerabilis* (Rathvon), terrapin scale, *Lecanium*

nigrofasciatum Perg., spruce bud scale, *Physokermes piceae* (Schr.), fletcher scale, *Lecanium fletcheri* Ckll., and others.

In cold climates, most soft scales overwinter as first or second instars, resume feeding in the spring, and mature during early or mid-summer. Then each female lays up to several hundred eggs beneath its body. These hatch in 2 to 3 weeks and the crawlers emerge, settle, and start to feed. In some cases, such as the terrapin scale, females do not lay eggs but give birth to live young. During the next 1½ months the female molts twice, the male four times, before mating. In the northern United States, there is usually one generation per year, but there may be two or more in southern localities.

The females of soft scales do not excrete a waxy covering as the armored scales do. Instead, the chitinized body of the female is like an inverted cup, under which the eggs are laid. Some

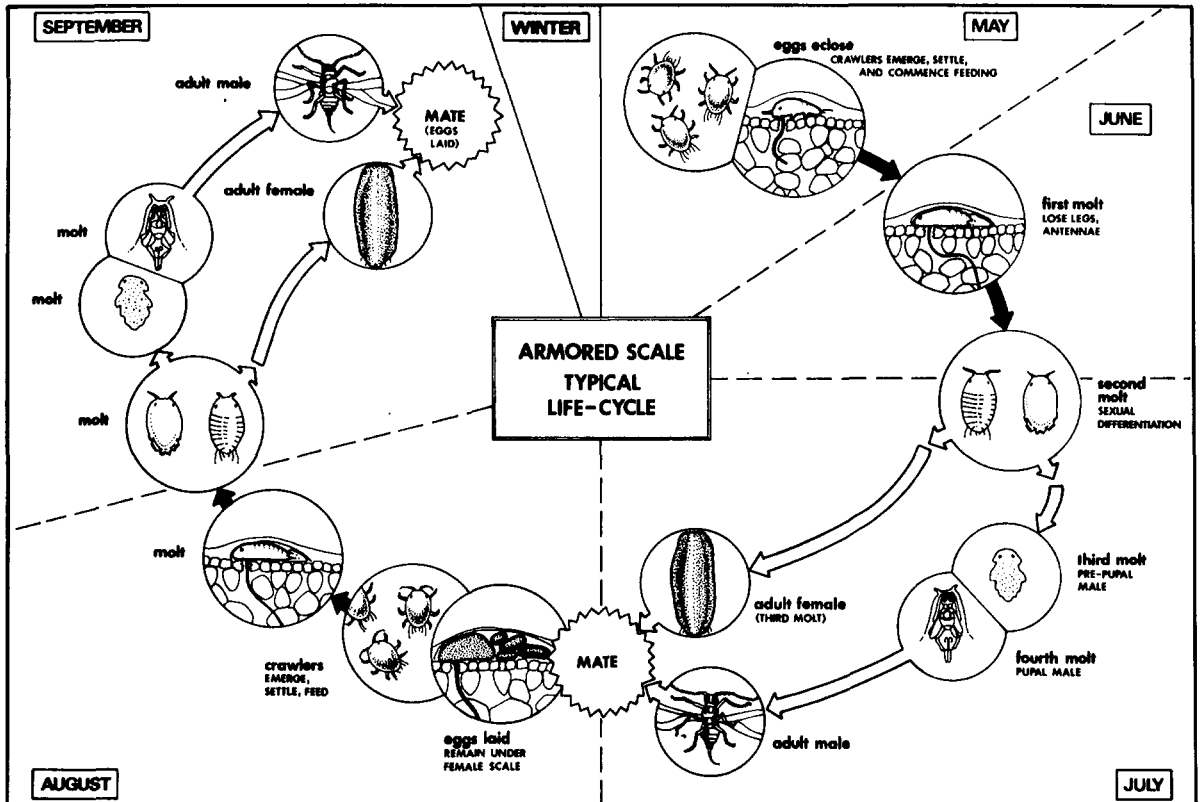


Figure 1. Generalized life cycle for an armored scale in a northern climate. Typical examples are pine needle scale, fiorinia hemlock scale, and oystershell scale.

species, such as cottony maple scale, secrete a mass of filamentous wax (called an ovisac) which receives the eggs (Fig. 2). The male is similar in development and appearance to the armored scales.

Feeding Biology. Scale insects, once they settle, remain attached to the host for the rest of their lives. They depend upon a long feeding tube (stylet) for obtaining plant sap. The stylet is normally 6 to 8 times the length of the scale's body; this permits the immobile insect to feed extensively within the host's tissues.

The stylet originates as four separate bristles in coils on each side of the labrum; these unwind in two directions, interlock as they issue through the labrum, and penetrate the plant (Fig. 5). The bristles are grooved so that as they interlock, two canals are formed within the stylets; a food canal for sucking up plant juices, and a salivary canal that liberates digestive enzymes. They penetrate

the leaf tissue directly between epidermal cells or through natural plant openings such as stomata (Fig. 6). Penetration of bark or woody tissue is not clearly understood, but direct entry with the aid of digestive enzymes or through lenticels is believed to be the most common method. A new set of stylets is formed with each molt and the old stylet remains within the host tissues.

Injury

Injury to plants is inflicted through feeding (withdrawing sap reduces tree vigor) but in other cases galls or pits are formed. Damage is normally insidious; plants suffer reduced photosynthetic activity and are weakened, and gradually individual branches or portions of trees or shrubs may die. Additionally, the feeding tubes may provide portals for entry of fungi (Shigo 1976) or physically disrupt normal tree functions (Wallner 1965).

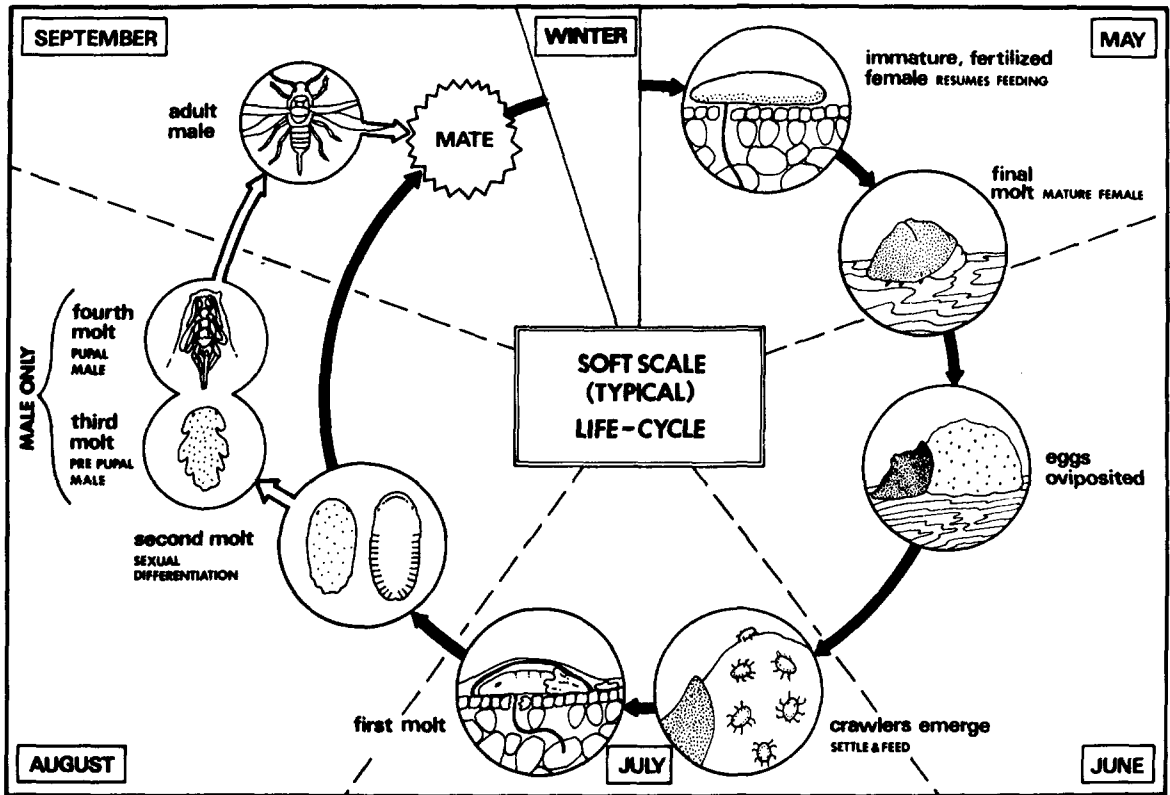


Figure 2. Generalized life cycle for soft scale under climatic conditions of northern United States. Examples of this type of scale include European fruit lecanium scale, cottony maple scale, and terrapin scale.

Climatic Effects

Climatic conditions can significantly alter the seasonal development of scale insects. For example, the pine needle scale has two generations per year in Connecticut, has both males and females, and overwinters in the egg stage. In Oregon, it consists only of females, has one generation per year, and overwinters as eggs and egg-laying females (Stimman 1969). Winter temperatures in Connecticut prevent females from laying eggs year around, whereas milder Oregon temperatures permit egg-laying throughout the winter; this results in both females and eggs being present.

Microclimatic conditions can produce differences in development of scales on the same trees. Koehler et al. (1965) found that crawlers of the irregular pine scale, *Toumeyella pinicola* Ferris emerged as much as 1 month earlier from twigs on south and west exposures as from other locations on the tree. Crawler emergence will vary from year to year depending upon the weather. Since insects respond directly to weather, hot or cold periods can accelerate or retard egg hatch and crawler emergence. Insect activity often can be correlated with the

phenological development of certain plants. For example, pine needle scale crawlers are at peak emergence when lilac is in full bloom.

Weather influences scale survival. Overwintering second instars of the tulip tree scale, *Toumeyella liriodendri* (Gmelin) were killed by ice that physically removed scales from the bark (Burns and Donley 1970). Low temperatures can limit the distribution of a species, as is the case with the introduced red pine scale, *Matsucoccus resinosa* Bean and Godwin. Temperatures of (10 deg. F or lower can kill up to 99% of overwintering first instars (Hartzell 1957). High temperatures, at critical periods of the life cycle, can

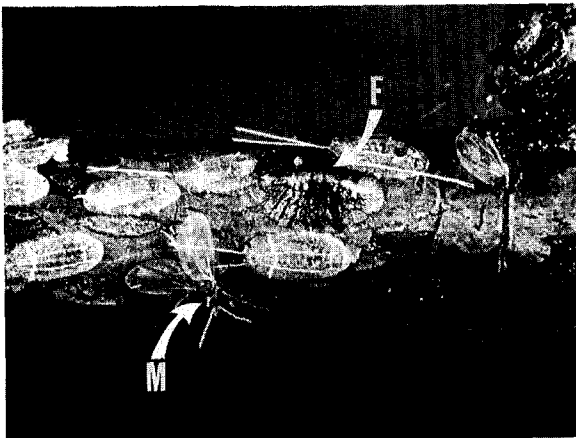


Figure 3. Infestation of terrapin scale showing adult male (M) and female (F). Scales attach themselves to their hosts with their feeding tubes and later secrete wax which further anchors them to their hosts. Scales remain attached to the tree long after they are dead, which complicates control evaluation.

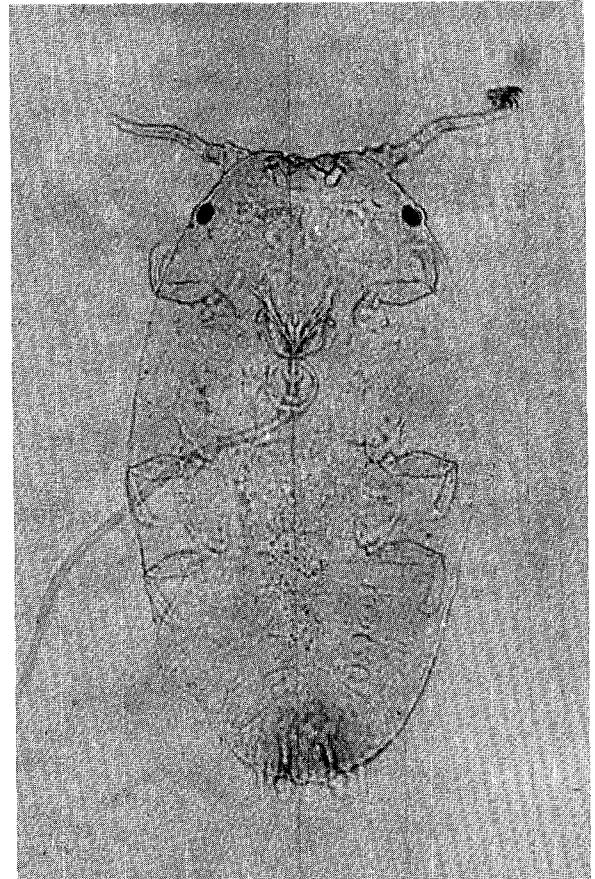


Figure 4. First instar crawler showing eggs, eyes, antennae, and long flexible feeding tube (stylet). This is the sole natural dispersal stage for establishing new scale insect infestations.

also adversely affect certain scales. Bailey (1964) reported that mortality of crawlers of the European fruit lecanium was related to the number of days during June when temperatures exceeded 90 deg. F.

Control

There are two periods in a scale's life cycle at which controls are normally directed; the crawler stage and overwintering stage. The timing differs between scale species.

Armored scales most often overwinter as eggs or mature females, whereas the majority of soft scales overwinter as immature females. In any geographic location this difference in phenological development translates into ap-

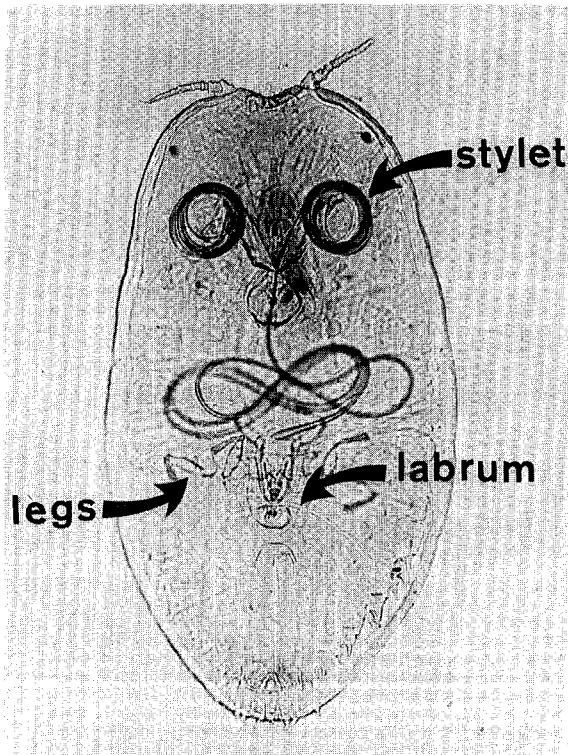


Figure 5. Molting second instar scale. Note the cast labrum and legs of the first instar and the new sets of stylets which unwind like coiled springs through the labrum. The stylets are composed of four bristles which interlock to form a feeding tube 6 to 8 times the length of the insect's body.

proximately 1 month difference in crawler emergence (Figs. 1, 2) between soft and armored scales. Therefore, chemicals used against one would be ineffective for the other because of the differential in emergence. The way to ensure proper timing of controls is to inspect scales with a hand lens and apply chemical sprays to control crawlers when approximately 60 to 70% of the eggs have hatched. Dormant sprays are commonly used and appear to be efficient in controlling most overwintering scales. However, some armored scales are less susceptible since the female and eggs are protected from the dormant spray by the female covering. In such cases crawler control is the preferred treatment. The developmental stage will also influence vulnerability as was reported by Ebeling (1936), who found that immature California red scales were more easily controlled than adults. Since they were less firmly fixed to the bark and their breathing pores (spiracles) were closer to the margin of their bodies, less dormant oil was needed to kill them. The time of treatment during

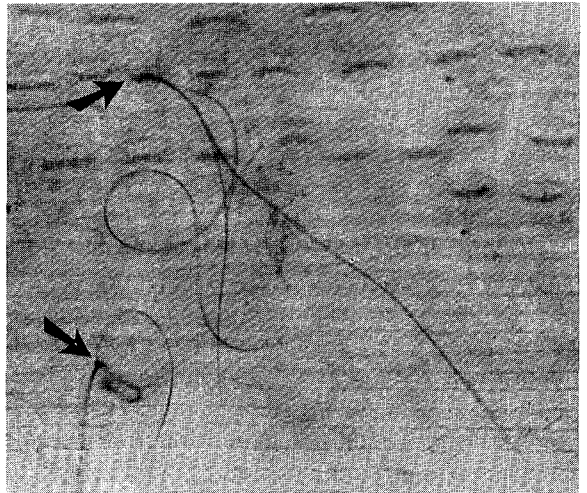


Figure 6. A scale-infested needle from which the insects' bodies have been detached from their feeding tubes (stylets). The stylets are shown here penetrating leaf tissue directly between epidermal cells and through stomatal openings. These feeding tubes disrupt normal plant functions and may create portals of entry for diseases.

scale dormancy may also influence vulnerability to insecticides. Phillips and Smith (1963), working with European fruit lecanium scale, found that control with dormant oil sprays diminished with increasing scale maturity. This was attributed to the thickening of the scale's body and the deposition of waxy secretions along the margin which prevented the oil from reaching the ventral surface and filling the spiracles.

Scale insects are difficult to control. Since they feed upon plant sap, it seems that systemic insecticides (chemicals that are absorbed by the plant) would give excellent control any time the scale is feeding. This has not proven to be true. Most chemical controls applied during the growing season must coincide with crawler emergence or must attack crawlers that have recently settled. Satisfactory results will usually require application of treatments over a 2- to 3-year period. Assessment of the need for, or the results of, control attempts is not a simple process. The number of scale covers observed is not always an accurate indicator, since even when dead they remain attached to their hosts for longer than a year. Host recovery following control efforts is seldom dramatic or predictable. In some cases, even though the scale is controlled, the injury to the host is irreversible and it dies. These facts support the need for accurate assessment, and careful choice of control and timing for each scale species.

Biological Control. Biological control of scale insects has produced some spectacular results. Of all complete biological control successes, 67% have been against scale insects. Some degree of control has been achieved with 64 species, suggesting that scales are more amenable to biological control than other insect and mite pests (DeBach et al. 1974). Perhaps the most notable is the control of the cottony cushion scale, *Icerya purchasi* Maskell, in California by the predatory ladybird beetle, *Rodolia cardinalis* (Mulsant). Introduced from Australia in 1888, the ladybird completely suppressed the scale within 2 years. There have been numerous attempts and successes against other scales, most of them food crop pests. Generally speaking, scales on forest and shade trees and ornamentals have

received little attention.

Successful biological control is usually not accidental, but results from intensive planning and careful execution. Many scale pests of trees and shrubs have native natural enemies that exert some degree of control. *Aspidiotiphagus citrinus* Craw., which attacks florinia hemlock scale (Fig. 7), and the twice stabbed ladybird beetle, *Chilocorus stigma* (Say), which feeds upon pine needle scale, beech scale, Terrapin scale, and others, seldom produce dramatic reductions in scale numbers until after substantial tree damage has occurred. However, DeBoo and Weidhaas (1976) working in Scots pine plantings in New York found that *C. stigma* can cause substantial reductions in pine needle scale populations. They suggest that by introducing large numbers of *C.*

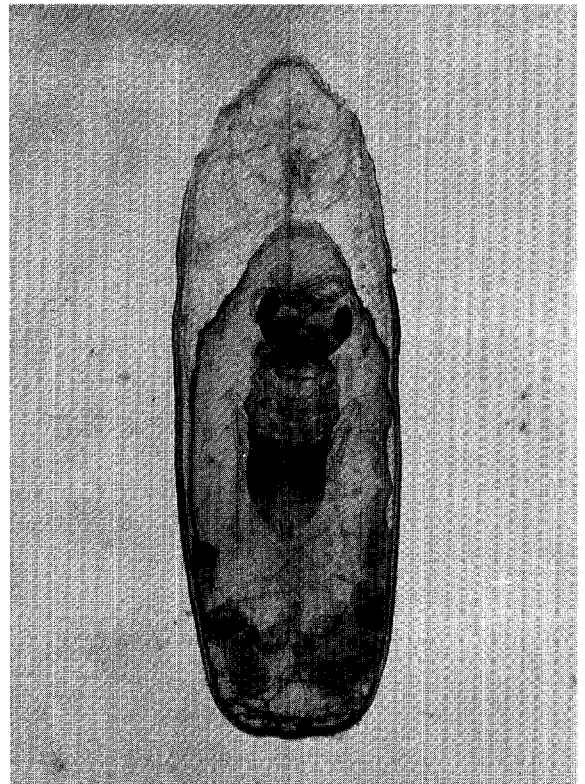


Figure 7. An armored scale infested with the parasite *Aspidiotiphagus citrinus* (Craw.). Biological control of scale insects is an important regulating mechanism which can be integrated with other control methods.

stigma adults during peak periods of scale infestation and keeping chemical treatments to a minimum that tree damage can be minimized and efficient control achieved. Generally speaking though, introduced parasites and predators have produced more dramatic results than manipulation of native species.

Local releases of ladybird beetles purchased in one location in the United States and released in another have, to date, resulted in little control of shade-tree scale pests. However, this is not to say that a well conceived program integrating various techniques (biological, chemical, cultural, genetic, etc.) cannot succeed; the recent success of parasites introduced to control aphids on shade trees in Berkeley, California, has demonstrated the biological and economic feasibility of such programs (Olkowski et al. 1974). But a more complete understanding of the biology of scale pests of shade and ornamental trees is fundamental to biomanipulation.

Summary

Scale insects have unique characteristics that make them a formidable challenge to the arboriculturist. Integrated methods of control that have long-term economic advantages appear most promising. However, researchers need to recognize that they must make significant contributions before any management system can be engendered. Specifically, information is needed on biology, effects of pollutants, host plant relationships, and control (biological, chemical, and cultural). The arboriculturist, on the other hand, must be able to diagnose scale-related from other types of plant deterioration and be prepared to implement new innovative management procedures.

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USDA, Forest Service
Forest Insect and Disease Laboratory
Hamden, Connecticut